IJSPT

SYSTEMATIC REVIEW WITH META-ANALYSIS

IS MULTI-JOINT OR SINGLE JOINT STRENGTHENING MORE EFFECTIVE IN REDUCING PAIN AND IMPROVING FUNCTION IN WOMEN WITH PATELLOFEMORAL PAIN SYNDROME? A SYSTEMATIC REVIEW AND META-ANALYSIS.

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ABSTRACT

Background: Patellofemoral pain syndrome is one of the most common causes of knee pain, especially in the female population. Conflicting evidence exists on whether a multi-joint strengthening program produces a greater outcome when compared to a single joint approach.

Purpose: The aim of this systematic review and meta-analysis was to investigate the effectiveness of a multi-joint strengthening program compared to a traditional single joint strengthening program in reducing pain and improving function in females diagnosed with patellofemoral pain syndrome.

Study Design: Systematic Review and Meta-Analysis.

Methods: A computer-based search (*population:* women with patellofemoral pain syndrome, *intervention:* multi-joint strengthening exercises, *comparator:* single joint strengthening exercises, *outcome:* pain and function) was performed. Databases including PubMed, CINAHL, SPORTDiscus, Cochrane, PEDro, and Scopus were searched up to May 23, 2017 for randomized clinical trials published since 2004. A hand search of relevant articles and exploration of Grey Literature (including clinical trials.gov, Grey Literature Report, and Open Grey) was also completed. Data was extracted for the following information: exercises prescribed, outcome measures, and overall results from the study.

Results: Five studies, each of high quality based on the PEDro scale, met the inclusion criteria for this systematic review and meta-analysis. Statistically different outcomes were found that favored the multi-joint intervention group for short-term and long-term self-reported pain and functional pain, short-term functional performance, and long-term self-reported function.

Conclusion: The results of this review show that statistically significant data are available that favor implementing a multi-joint exercise program in comparison to a single joint program for the reduction of pain in females with patellofemoral pain syndrome. Limited statistical evidence, however, is available to support a multi-joint program over a single joint program in the improvement of short-term functional performance and long-term self-reported function in females with patellofemoral pain syndrome.

Key words: Hip, knee, multi-joint, patellofemoral pain syndrome, single-joint, strengthening program.

Level of Evidence: 1a

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INTRODUCTION

Patellofemoral pain syndrome (PFPS) is one of the most common causes of knee pain in many populations.[1-6] PFPS is caused by many different factors, including increased foot pronation, increased internal rotation (IR) of the tibia with increased valgus stress, excessive lateral tracking of the patella, muscle imbalance, or overuse.[1,2,4-6] Women in particular are prone to biomechanical disadvantages including decreased quadriceps and hip external rotator strength, altered kinematics with dynamic tasks, increased Q angle, and increased hip IR, all of which may predispose women to the symptoms associated with PFPS.[1,7]

Given these biomechanical factors, women experience an increased prevalence of PFPS when compared to their male counterparts. The prevalence has been reported as high as 1.5 times greater in females than in males.[8] Due to the increased prevalence of females experiencing symptoms of PFPS, attention to females when investigating treatment options is imperative.

During stair navigation, all females demonstrate hip adduction and knee abduction, while individuals already diagnosed with PFPS display greater ipsilateral trunk lean, contralateral pelvic drop, hip adduction, and knee abduction when compared to males and individuals not diagnosed with PFPS.[9] These results suggest that the female population, as a whole, present with similar biomechanical factors, whether or not they have been diagnosed with PFPS, resulting in a functional disadvantage. The deficits observed with stair negotiation suggest that PFPS occurs as a result of weak hip and knee joint muscles. Focusing on strengthening of the hip abductors could decrease ipsilateral trunk lean, contralateral pelvic drop, and hip adduction, while focusing on strengthening the primary movers of the knee joint could decrease knee abduction. Two randomized controlled trials that compared hip only strengthening interventions to knee only strengthening interventions found that individuals in the hip intervention groups experienced a decrease in pain sooner than the knee only intervention groups, although both intervention groups showed similar improvements in symptoms during a longer follow up period.[10,11] This suggests that implementing a multi-joint exercise program that addresses both the hip and knee joints would likely be beneficial to reduce pain and functional impairments experienced with PFPS.

Several researchers have examined the effectiveness of combined hip and knee strengthening on decreasing symptoms of PFPS, but fewer have examined the effects of this treatment on women specifically. Two recent systematic reviews found that a hip and knee strengthening protocol reduced pain and improved function for both short- and long-term periods following intervention.[5,12] Another recent study contrasted these findings, reporting that hip and knee strengthening are equally effective in reducing pain and improving function, with limited evidence to support the benefits of the addition of hip strengthening.[13]

Limited high-quality evidence exists on whether or not the addition of hip strengthening is beneficial in decreasing pain and improving function in patients with PFPS.[14] Additionally, no systematic reviews were found that focus on the female population alone. Thus, the aim of this systematic review and meta-analysis was to investigate the effectiveness of a multi-joint strengthening program compared to a traditional single joint strengthening program in reducing pain and improving function in females diagnosed with patellofemoral pain syndrome.

METHODS

Research topic, pilot title, and protocol were registered online on the PROSPERO database with registration number: CRD42016051313. The Reporting Checklist for Meta-Analyses of Observational Studies (MOOSE) guidelines were utilized throughout the research process.[15]

Eligibility Criteria, Search Strategy, and Study Selection

Eligibility for this review included randomized controlled trials that compared multi-joint and single joint exercise programs in women diagnosed with PFPS (described as patellofemoral pain, patellofemoral pain syndrome, or anterior knee pain), but no other concurrent knee conditions. Studies must have included outcome measures assessing pain and function, as well as reported outcomes separated by gender. Multi-joint exercises were defined as therapeutic exercise that focused on strengthening the musculature about more than one joint, including at least the hip and knee. Single joint exercises were defined as exercises strictly focusing on strengthening at the musculature of the knee joint (closed kinetic chain or open kinetic chain approach). While exercise protocols investigating a single joint (either the knee or hip) will inherently produce activation of muscles spanning both joints (i.e. the quadriceps), the sole focus of a single joint protocol is the activation of the primary movers of that joint. For example, while the ascending portion of a standing squat requires hip extension and utilizes specific musculature required for that motion, the focus of the exercise is knee extension and the concentric activation of the quadriceps musculature. Examples of common exercises that were used in the studies included in this review for both the multi-joint and single joint groups can be found in Table 1. Studies published prior to 2004 were not included in order to focus on the most recent literature on this topic. While studies regarding this topic were published prior to 2004, the majority of high quality studies focusing specifically on females with the syndrome have been published within the past 13 years. Non-English studies were also excluded.

Electronic databases including PubMed, CINAHL, SPORTDiscus, Cochrane, PEDro, Scopus were searched in consultation with a librarian on November 20, 2017 and May 23, 2017. Keywords included "PFPS," "anterior knee pain," and "patellofemoral pain". An example of a specific search strategy used can be found in Table 2. A hand search of relevant articles and exploration of Grey Literature (including clinicaltrials.gov, Grey Literature Report, and Open Grey) were also completed for any additional studies not identified in the database search.

After duplicates were removed, titles were screened by two authors and disagreements were resolved by a third author. Screening of abstracts was completed by four authors and any disagreements were discussed with unanimous consensus reached for inclusion. Further screening of full texts was completed by two authors and all disagreements were resolved by a third author. Search results are displayed in Figure 1.

Quality Assessment

Quality assessment of articles was completed by two authors and any discrepancies that arose were settled by a third author. Methodological quality of each study was assessed using the PEDro scale,[16] which consists of 11 items, each of which is scored by a "yes" or a "no" response. A "yes" is equivalent to one point on the scale and is only assigned if the criteria are specifically stated within the text. A "no" is assigned to categories not specifically stated within the text. Specific guidelines and criteria for

Table 1. *Sample exercises for multi-joint and single joint protocols*[30-32,34]

Multi-Joint (Hip and Knee)	Single Joint (Knee Only)
• Standing or sidelying hip abduction • Sidelying or sitting hip external rotation • Sitting hip internal rotation • Sidelying, prone, or standing hip extension • Resisted side stepping • Forward lunge • Squats • Prone knee flexion • Seated knee extension	• Quad sets • Supine straight leg raise • Seated knee extension • Prone knee flexion • Leg press • Squats/Wall squats* • Step ups/step downs*
*Note: Because many exercises will produce muscle activation that crosses both joints (i.e. the quadriceps), single joint exercises are defined by the primary mover of the joint during the activity. For example, a squat requires some hip extension, but the main focus of the exercise is knee extension, requiring concentric activation of the quadriceps.	

Table 2. *Example search strategy entered into PubMed*

("Patellofemoral Pain Syndrome"[Mesh] OR "patellofemoral pain") AND (Exercise OR Strengthening OR Resistance Training[Mesh]) AND (Hip OR Knee OR Proximal Musc* OR Gluteus*)

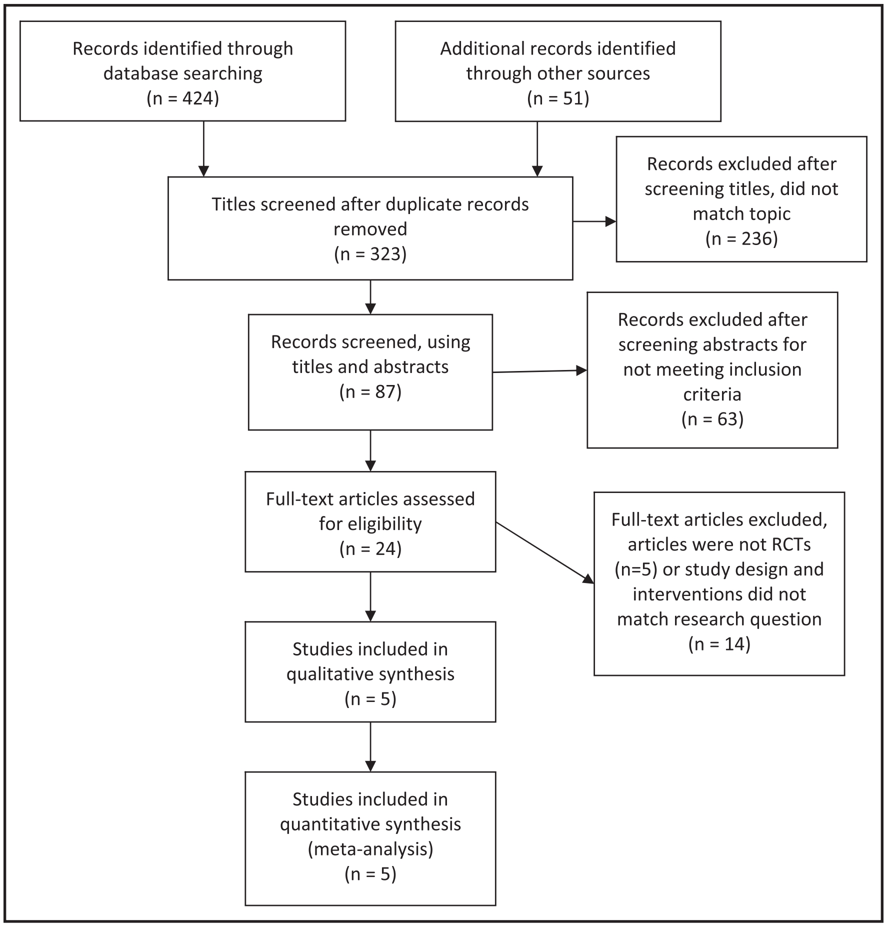

Figure 1. *Prisma flow diagram.*

the grading with the PEDro scale are outlined in Verhagen et al.[16] The reliability of the PEDro scale has been assessed as having inter-rater reliability ranging from moderate to substantial reliability (κ = .50 – .79).[17] Using the PEDro scale for assessment, the articles with more "Yes" scores are of higher quality given the scale of the assessment.[18]

Data Extraction and Analysis

The outcome measures were categorized into four groups based on the constructs investigated, and included self-reported pain at rest, functional pain, self-reported function, and functional performance. Self-reported pain at rest is a subjective report of pain while the individual is not completing any physical activity. This is measured by the Visual Analog Scale (VAS). Functional pain is a subjective measure of pain that the individual experiences while performing physical activity or activities of daily living (ADLs) and is also measured by the VAS and Numeric Pain Rating Scale (NPRS). Both the VAS and the NPRS have been found to have excellent and high test-retest reliability ($r = 0.97$ and $r = 0.92$ respectively).[19, 20]

Self-reported function is a subjective report of the individual's functional ability to perform daily activities and is measured by the Lower Extremity Functional Scale (LEFS), the Anterior Knee Pain Scale (AKPS), or the Kujala Function Score. The LEFS and Kujala have each been found to have excellent test-retest reliability ($r = 0.94$ and $r = 0.944$ respectively),[21, 22] while the AKPS was shown to have excellent inter-rater reliability ($r = 0.95$).[23] Finally, functional performance testing is an objective measure of functional ability and these investigate either muscle power measured by the Single Limb Hop Test or muscle endurance measured by the Step Down Test or Single Leg Squat Test. The single limb hop test is an assessment of lower extremity function that measures the distance jumped by the study participant in a single attempt. The single limb hop test has been reported to produce high inter-rater reliability (ICC = 0.77-0.99).[24] The step down test is performed with the participant keeping the testing leg on a raised platform while the contralateral limb descends to a lower surface. The step down test has been reported to have high intra-rater reliability (ICC = 0.94).[25] The single leg squat is performed in single leg stance by flexing and extending the knee to a predetermined angle in a controlled manner. Both tests are quantitative assessments of lower extremity function as they measure the number of repetitions of these exercises completed by the subject in a given time frame. Established reliability values were not found for the single leg squat test.

Data extraction was completed by four authors who independently collected pertinent data from each included study. All data was cross-checked by another author. Participant inclusion/exclusion criteria, sample size, interventions, and follow-up times were synthesized as well as means, medians, standard deviations, and p-values for the multi-joint and single joint groups in each study.

Meta-analyses were made using Comprehensive Meta-Analysis, Version 3 wherever possible. All meta-analyses were completed using standardized mean difference (SMD) as the summary measure of effect. SMD with 95% confidence intervals (CI) were used as this method is seen to be more generalizable and also allows the use of different scales to assess the same general construct. I^2 statistics were calculated in order to determine the level of heterogeneity or lack thereof between included studies. The I^2 statistic is more useful than the Q test, which only indicates the presence versus absence of heterogeneity.[26] Percentages used by Higgins and Thompson[27] were utilized to quantify the magnitude of heterogeneity: 25% = low, 50% = medium, 75% = high heterogeneity. Utilizing the scale, if I^2 was < 50%, a fixed effects model was used, and if the I^2 was > 50%, a random effects model was used. Interpretation of effect size used Cohen's criteria for pooled estimates.[28] Cohen describes 0.2 as small, 0.5 as moderate, and 0.8 as large effect sizes.[27]

Risk of bias was assessed via funnel plot construction. A symmetrical funnel plot indicates low risk of publication bias, whereas an asymmetrical funnel plot indicates a higher risk of publication bias.[29]

RESULTS

The search process returned 475 records on this topic. There were 470 articles excluded through title, abstract, and full-text assessments because they did not meet inclusion criteria, were not randomized controlled trials, or the study design and interventions did not match the research question. The remaining five studies were used to complete this systematic review and meta-analysis.[30-34] Substantial agreement between reviewers was demonstrated in the title screening process, with κ = 0.719 (95% CI, 0.632 to 0.805) $p < .05$, and excellent agreement between reviewers was found during the full-text screening process, with κ = 0.915 (95% CI, 0.753 to 1) $p < .05$.[35] The methods of the study selection and exclusion are shown in figure 1.

Quality Assessment

The five included articles[30-34] were assessed using the PEDro scale with κ = 1.0 (95% CI, 1.0 to 1.0) $p < 0.05$, demonstrating excellent agreement between reviewers.[35] Each of the included articles[30-34] received scores of at least 8. Given the scores as assessed by the PEDro scale, all included articles are of high quality.[18] All five studies[30-34] used assessor blinding to decrease the risk of measurement bias, used concealed assignment to randomize the subjects in each group, and all groups were statistically similar prior to intervention, which reduced the risk of selection bias. Results from the PEDro quality checklist assessment are summarized in Table 3.

Study Characteristics

Individual study details including sample size, patient age, intervention and comparison group protocols, results, and exercise prescription are presented in Table 4. All included studies investigated exercise protocols of the hip and knee musculature in comparison to exercise protocols of knee musculature only. The results of each of these studies were categorized into two different time periods: short-term and long-term. The short-term period was defined as the timeframe that treatment was provided. The long-term period is defined as the follow-up period after treatment has ended. During the short-term period, treatment duration lasted either four, six, or eight weeks. The long-term follow-up period lasted 12 weeks. No structured intervention

Table 3. *Quality Check Assessment*

	Criteria											
Author	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**Total Score**
Baldon et al.[30]	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	9
Fukuda et al. (2010)[31]	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	9
Fukuda et al. (2012)[32]	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	9
Razeghi et al.[33]	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	9
Sahin et al.[34]	Y	Y	Y	Y	N	N	Y	Y	N	Y	Y	8

I = Eligibility criteria specified; II = Random allocation of subjects; III = Concealed allocation of subjects; IV = Groups similar at baseline; V = Subject blinding; VI = Therapist blinding; VII = Assessor blinding; VIII = Outcome measures obtained from >85% of subjects; IX = Treatment received or gave intention to treat; X = Between-group statistical comparison; XI = Within-group statistical comparison; Y = Yes; N = No

was performed during the follow-up period. Data were analyzed separately for short-term and long-term periods.

Effects of Multi-Joint Compared with Single Joint Exercise Programs

All five studies[30-34] compared multi-joint exercise programs with single joint exercise programs in females. Outcome measures of four of the five studies evaluating pain and function were assessed at two different time points: pre and post treatment (short-term).[30,31,33,34] Three of the five studies[30,32,34] also evaluated pain and function after treatment was ended (long-term). Four out of five studies provided clear outlines of the exercise programs performed per each intervention group.[30-32, 34] Razeghi et al. only provided the targeted muscle groups in each of the intervention categories and did not include specific exercise protocols that participants followed.[33] A summary of meta-analysis results can be found in Table 5 and Table 6.

Self-Reported Pain at Rest

Three of the five studies[30,33,34] used in the meta-analysis examined self-reported pain utilizing the VAS scale. In the short term, evidence suggests a large effect[28] and a significant decrease in pain (SMD, 0.87, CI: 0.48, 1.26, $p \leq 0.001$) favoring multi-joint interventions over single joint interventions (Figure 2A). Two studies[30,34] were included in the meta-analysis of the long-term period, and evidence demonstrated a large effect [28] and a significant decrease in pain (SMD, 0.89, CI: 0.43, 1.34, $p \leq 0.001$) in favor of multi-joint interventions over single joint interventions (Figure 3A). Heterogeneity for self-reported pain at rest was low for both short- and long-term effects (I^2 = 0). See Tables 5 and 6 for meta-analysis results.

Pain During Functional Activities

Three of the five studies[31,32,34] used in the meta-analysis investigated pain during functional activities. Activities analyzed included pain with ascending and descending stairs, ramp negotiation, running, squatting, standing, and walking. Results demonstrated significant decreases in pain with a variety of activities and a moderate short-term (SMD, 0.46, CI: 0.05, 0.88, $p = 0.03$) and a large long-term effect (SMD, 0.97, CI: 0.02, 1.93, $p = 0.05$) in favor of multi-joint interventions over single joint interventions (Figures 2B and 3B respectively). Heterogeneity for self-reported pain at rest during the short term was low (I^2 = 0) and was high for the long-term effects (I^2 = 77.34). See Tables 5 and 6 for meta-analysis results.

Self-Reported Function

Four of the five studies[30-32,34] used in the meta-analysis investigated self-reported function but utilized different questionnaires as their subjective measures (Kujala, AKPS, and LEFS). Three of the four studies[30,31,34] analyzed self-reported function in the short term, and did not demonstrate statistically significant improvements in self-reported function in favor of multi-joint interventions over single joint interventions but did report a moderate effect size

Table 4. *Individual Study Demographics*

Author	Sample Size (n)	Participants (Age: Mean +/- SD in Years)	Intervention Group (Multi-Joint)	Control Group (Single Joint)	Outcome Measures	Results
Baldon et al.[30]	31 females Multi-joint group: n= 15 Single joint group: n=16	Multi-joint group: 22.7 +/-3.2 years Single joint group: 21.3 +/-2.6 years	Duration: 8 wks Exercise: 3 sessions per week with sessions lasting 90-120 minutes; motor control and strengthening exercises of increasing difficulty of trunk, hip, and knee muscles, patient education about how LE malalignment can increase symptoms of PFPS	Duration: 8 wks Exercise: 3 sessions per week with sessions lasting 75-90 minutes; stretching plus weight bearing and non-weight bearing quadricep strengthening	VAS, LEFS, and Triple Hop Test 2 mos and 5 mos after intervention	Significant changes in VAS in both groups and in the Triple Hop Test in the intervention group (p<0.05); significant between-group difference in the Triple Hop Test (p<0.05)
Fukuda et al, 2010[31]	70 females Multi-joint group: n=23 Single joint group: n=22	Multi-joint group: 25 +/- 7 years Single joint group: 25 +/- 6 years	Duration: 4 wks Exercise: 3 treatment sessions per week; exercises focused on stretching and strengthening of the knee, hip abductor, and hip lateral rotator muscles	Duration: 4 wks Exercise: 3 treatment sessions per week; exercises focused on stretching and strengthening of the knee musculature	LEFS, AKPS, Single Hop Test, NPRS Ascending, and NPRS Descending after 4 wks	Significant improvement for the LEFS and AKPS in the intervention group (p<0.01) and control group (p<0.05); significant improvement in the single hop test in both groups (p<0.05); no significant difference between groups for any of the outcome measures (p>0.05)
Fukuda et al, 2012[32]	54 sedentary females Multi-joint group: n=28 Single joint group: n=26	Multi-joint group: 22 +/- 3 years Single joint group: 23 +/- 3 years	Duration: 4 wks Exercise: 3 treatment sessions per week; exercises focused on stretching and strengthening of the knee, hip abductor, and hip lateral rotator muscles	Duration: 4 wks Exercise: 3 treatment sessions per week; exercises focused on stretching and strengthening of the knee musculature	LEFS, AKPS, Single Hop Test, NPRS Ascending, and NPRS Descending after 3 mos, 6 mos, and 12 mos	Significant improvement in function and decrease in pain at 3, 6, and 12 months post-treatment in the intervention group (p<0.05); significant decrease in pain with ascending stairs at 6 months and descending stairs at 3 and 6 months, and improvement on the single hop test at 3, 6, and 12 months post-treatment in the control group (p<0.05)
Razeghi et al.[33]	32 female college students Multi-joint group: n=16 Single joint group: n=16	Overall: 22.62 +/- 2.67 years	Duration: 4 wks Exercise: Progressive resistive exercises to strengthen all hip musculature and knee extensors	Duration: 4 wks Exercise: Progressive resistive exercises to strengthen the quadriceps muscle	VAS after 4 weeks	Significant decrease in pain in the intervention (p=0.001) and control (p=0.005) groups; significantly greater reduction in pain in the intervention group compared to the control group (p=0.032)
Sahin et al.[34]	55 sedentary women Multi-joint group: n=28 Single joint group: n=27	Overall: 34.1 +/- 6.2 years	Duration: 6 wks Exercise: 5 treatment sessions per week; lower extremity stretching plus isometric and elastic resisted strengthening exercises focusing on the knee extensors, hip abductors, and hip lateral rotators	Duration: 6 wks Exercise: 5 treatment sessions per week; lower extremity stretches plus isometric and elastic resisted strengthening exercises focusing on the knee extensors	VAS at rest and with activities, Triple Hop Test, Single Leg Squat, Step Down Test, and Kujala Function Score after 6 wks and 12 wks	Significant improvement in pain with resting, standing, walking, running, squatting, stairs, and ramp at 6 and 12 weeks and prolonged sitting and kneeling at 12 weeks in the intervention group compared to the control group (p<0.017); significantly higher number of repetitions in the single leg squat test at 6 weeks in the intervention group (p<0.017); significantly higher number of repetitions in the step down test at 6 and 12 weeks in the intervention group (p<0.017); significantly higher scores on the Kujala scale in the intervention group (p<0.017)

SD = Standard Deviation; LE = Lower Extremity; PFPS = Patellofemoral Pain Syndrome; VAS = Visual Analog Scale; LEFS = Lower Extremity Functional Scale; AKPS = Anterior Knee Pain Scale; NPRS = Numeric Pain Rating Scale;

Table 5. *Meta-analysis for short term impact*

Outcome Category	Participants, n	Studies, n	Total I^2	p value	SMD	95% CI
Self-Reported Pain	MJ 56 SJ 57	3	0.00	0.00	0.87	0.48 – 1.25
Pain with Function	MJ 48 SJ 47	2	0.00	0.03	0.46	0.05 – 0.88
Self-Reported Function	MJ 63 SJ 63	3	0.00	0.13	0.50	-0.14 – 1.13
Function	MJ 63 SJ 63	3	67.48	0.02	0.44	0.08 – 0.80

MJ= Multi-joint; SJ= Single joint

Table 6. *Meta-analysis for long term impact*

Outcome category	Participants, n	Studies, n	Total I^2	p value	SMD	95% CI
Self-Reported Pain	MJ 40 SJ 41	2	0.00	0.00	0.89	0.43 – 1.34
Pain with Function	MJ 50 SJ 49	2	77.34	0.05	0.97	0.02 – 1.93
Self-Reported Function	MJ 50 SJ 49	2	71.13	0.01	1.36	0.30 – 2.41
Function	MJ 65 SJ 65	3	85.97	0.17	0.54	-0.22 – 1.31

MJ= Multi-joint; SJ= Single joint

(SMD = 0.50, CI: -0.14, 1.13, p = 0.13) (Figure 2C). Heterogeneity for self-reported function in the short term was low (I^2 = 0).

Two of the five studies[30,32,34] were analyzed with regards to long-term self-report of function and did demonstrate statistically significant improvements in self-reported function in favor of multi-joint interventions over single joint interventions with a large effect size (SMD = 1.36, CI: 0.30, 2.41, p = 0.01) (Figure 3C). Heterogeneity for self-reported function in the long term was high (I^2 = 71.13). See Tables 5 and 6 for meta-analysis results.

Functional Performance Testing

Four of the five studies[30-32,34] included in the meta-analysis investigated functional performance and used a variety of measures including the Single Hop Test, Triple Hop Test, Single Leg Squat, and Step Down Test. Functional performance during the short term was analyzed in three of the four studies.[30,31,34] The results demonstrate a statistically significant improvement in functional performance in favor of multi-joint interventions over single joint interventions (SMD = 0.44, CI: 0.08, 0.80, p = 0.02) (See Figure 2D). Two of the four studies[32,34] were analyzed with regard to long-term reports of functional performance, however, statistically significant improvements in function were not reported in favor of multi-joint interventions over single joint interventions with a moderate effect size (SMD = 0.54, CI: -0.22, 1.31, p = 0.17) (Figure 3D). Heterogeneity for functional performance was high for both short- and long-term effects (I^2 = 67.48; 85.97). See Tables 5 and 6 for meta-analysis results.

DISCUSSION

The goal of this systematic review and meta-analysis was to analyze the effectiveness of a multi-joint exercise protocol compared to a single joint protocol in reducing pain and improving function in females diagnosed with PFPS. Through meta-analysis of all five studies,[30-34] statistical significance was found that favored the multi-joint intervention group for short-term and long-term self-reported pain and functional pain, short-term functional performance, and long-term self-reported function. These findings suggest that strengthening musculature about both the hip and knee joints is more effective in decreasing pain and improving function in females with PFPS when compared to strengthening musculature about the

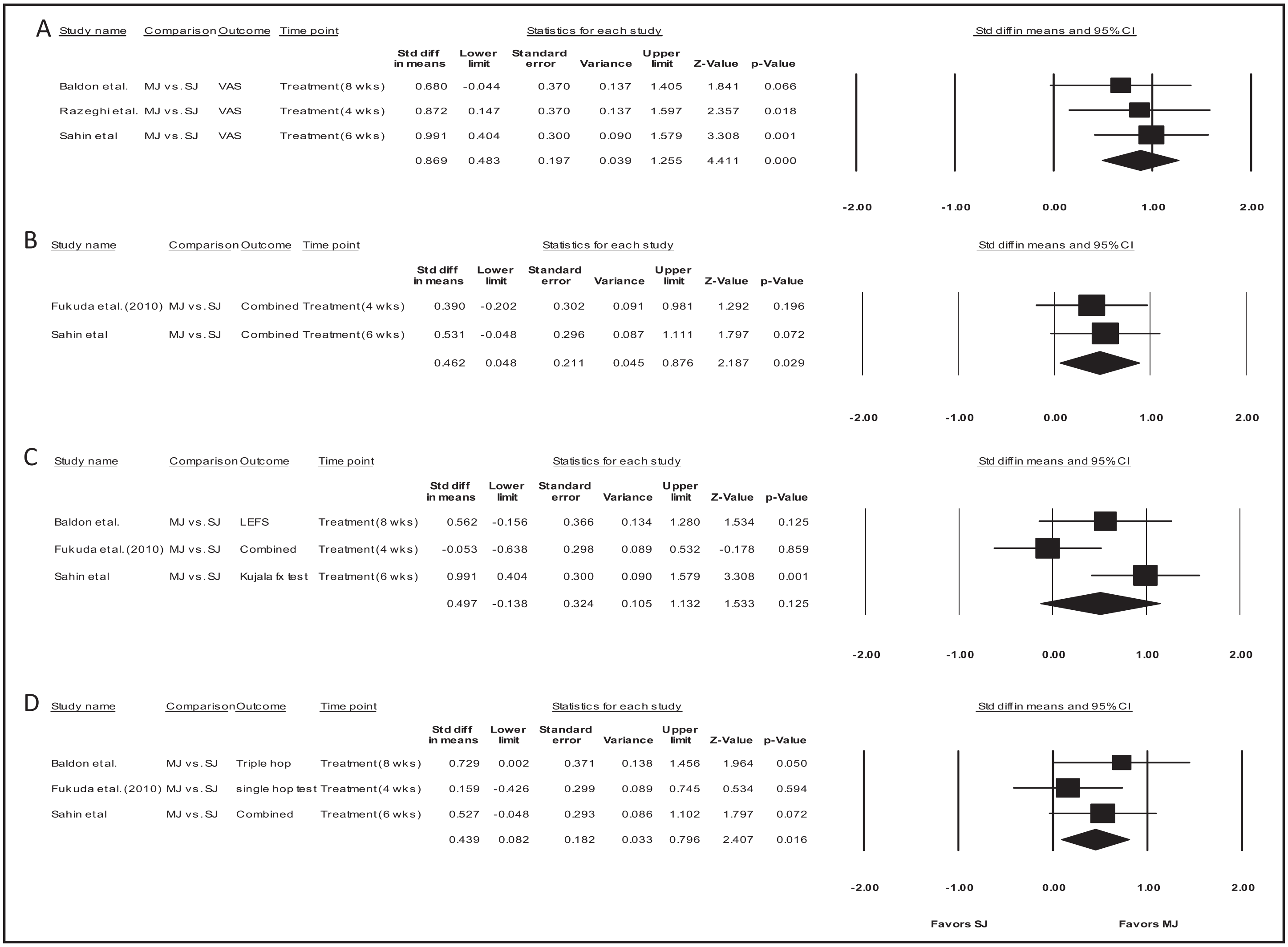

Figure 2. *Standard difference in means in individual studies for short-term (A) self-reported pain, (B) pain with functional activity, (C) self-reported function, and (D) function after completion of treatment. Squares represent study-specific findings and diamond represents summary estimates of fixed/random effects meta-analysis. SJ single joint, MJ multi-joint, CI Confidence Interval.*

knee joint alone. The results potentially support an intervention that may directly target the inherent mechanical disadvantage that women face at both the hip and knee joint. These disadvantages include an increased Q-angle, increased hip internal rotation, possibly resulting from decreased strength of the quadriceps and hip external rotators.[1,7] Strengthening the musculature about both the hip and knee joints could help to provide better stability and posture at both joints through improved neuromuscular activation, muscular hypertrophy, and increased muscle cross-sectional area which may counteract many of the inherent anatomical factors that predispose women to the symptoms of PFPS. This in turn may have a positive impact on pain and function in this population.

The Minimal Clinically Important Difference (MCID) for the VAS and NPRS has been reported as 1.4 and -1.5 to -3.5 respectively.[36,37] The MCID is the minimal change in a scale that can be detected as "different" from a patient's perspective and warrants a change in the intervention that is used for a particular condition. All included studies reported mean post-intervention pain changes that exceeded established MCID values. Multi-joint intervention groups also displayed mean changes in reported pain that were larger than the mean reported

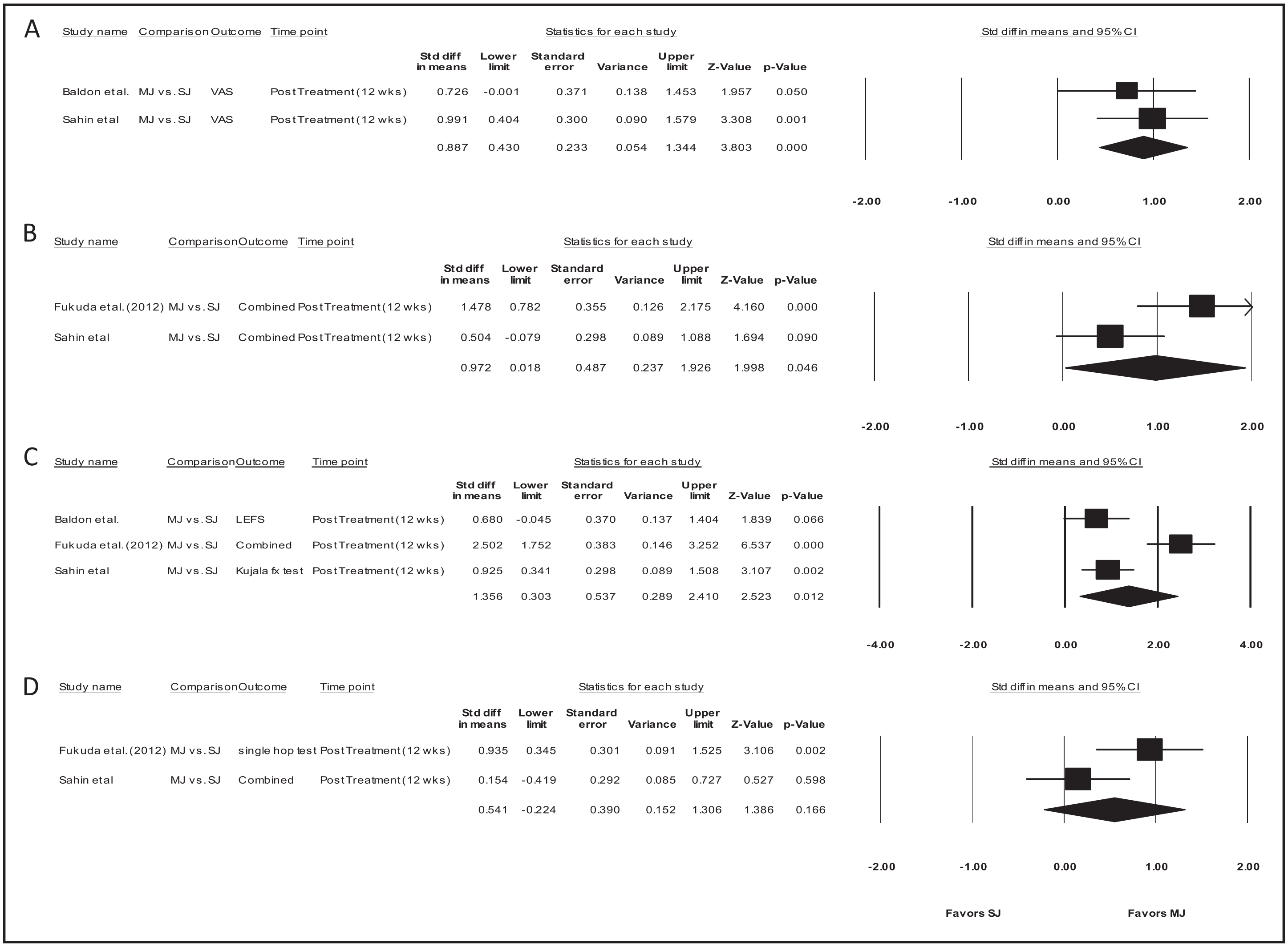

Figure 3. *Standard difference in means in individual studies for long-term (A) self-reported pain, (B) pain with functional activity, (C) self-reported function, and (D) function during the follow-up period. Squares represent study-specific findings and diamond represents summary estimates of fixed/random effects meta-analysis. SJ single joint, MJ multi-joint, CI Confidence Interval.*

changes in the single joint groups. This is clinically significant because individuals experiencing pain demonstrated improvement after using a treatment approach focused on both the hip and knee. Statistical significant outcomes with moderate to large effect sizes were found for decreasing pain at rest and with functional activities in favor of individuals completing a multi-joint exercise protocol when compared to those completing a single joint protocol. In addition, clinical and statistical significant differences found using the VAS and NPRS could be attributed to all included studies utilizing a validated subjective measure of pain, which provided a larger sample size from which to draw these conclusions. This data provides clinical and statistical significance, supporting the use of a multi-joint protocol in clinical practice.

Calculated effect size and statistical significance values were inconsistent throughout the self-reported function measures. While both the short-term and long-term periods demonstrated moderate to large effect sizes, the meta-analysis found statistical significant support for improvement in self-reported function for the long-term periods, but not short-term. When breaking down the short-term results, the study that least favored the multi-joint group consisted of a four-week strengthening protocol.[31] One possible explanation for this finding is that this shorter frequency and duration of treatment is not long enough to allow for significant muscle hypertrophy or biomechanical changes that would allow for a noticeable improvement in function. The literature has shown that four weeks is not long enough to create significant muscular hypertrophy and increases in muscular cross-sectional area.[38] The subjects that received at least six weeks of treatment may be more likely to demonstrate greater improvements simply because of increased strength gains, increased muscular hypertrophy, or other biomechanical improvements that may occur given a longer timeframe. In the study conducted by Fukuda et al.[31] the participants also received the lowest number of total treatments (12) while the other two studies who received significantly more treatment sessions (24 and 30, respectively).[30,31,34] This suggests that the dosage of training is a major factor in the design and implementation of multi-joint protocols.

Comparing the results of the studies with the established MCID values for the LEFS and AKPS may indicate possible clinical relevance for self-reported function during both short- and long-term periods despite the lack of statistical significance. The established MCID for the LEFS has been reported by a change of 12 points.[39] The three studies that used the LEFS as an outcome of self-reported function demonstrated results that were greater than the established MCID across all time frames.[30-32] Also, the MCID for the AKPS has been reported as an average of 10 points.[40] Both studies that included the AKPS as an outcome measure of self-reported function exceeded the MCID for the multi-joint group, while the single joint did not, thereby exhibiting clinically significant improvements in the multi-joint group.

Similar to self-reported function, the meta-analysis found moderate to large effect sizes and statistically significant outcomes in functional performance but for the short-term period and not the long-term. Several different functional performance tests were used across the studies, including the triple hop, single hop, step down, and single leg squat tests. One possible explanation for the variety of results found among these tests is the variance in the nature of the tests used. The single and triple hop tests are dynamic activities that rely on muscle power, whereas the step down and single leg squat tests are static activities that rely more on muscle endurance. No statistically significant difference was found in the one study[31] observing the single hop test over a period of only four weeks. This same test measure, however, was found to produce statistically significant differences in another study[32] over a 12-week period. The triple hop test was found to produce statistically significant differences favoring the multi-joint intervention over the single joint intervention for the triple hop test, but over a period of eight weeks.[30] As stated previously, it is very possible that the longer intervention periods allow for increased muscular strength compared to the shorter periods, producing better statistical results for the multi-joint group in comparison to the single joint group. The single study[34] that investigated the use of the step down and single leg squat test found statistically significant differences favoring the multi-joint group over the single joint group. These results were found over a six-week period, which is a relatively shorter time frame; however, the activities measured are more static activities, as opposed to more dynamic activities like the single hop and triple hop tests (Figures 2D and 3D). It is likely that static stability will develop before dynamic stability during training, and that the dynamic activities may be more difficult for a sedentary, untrained population, like the participants in these studies, who likely have less experience with activities requiring significant power. Another possible explanation is that some of the exercises performed in the training protocols are similar to the step down and single leg squat tests, which could give the participants an advantage over time. These factors, in addition to smaller sample sizes within each of these studies may have caused the variance in the results for functional performance. It should also be noted that the functional performance measures do not necessarily correlate with return to higher level activities such as sport. Rather, these tests display an ability to dynamically control the knee joint and surrounding musculature, which may correlate with normal activities of daily living such as ascending and descending stairs.

Two major limitations of the studies analyzed in this meta-analysis exist. First, the included studies had relatively low sample sizes ranging from n = 31 to n = 64. Second, differences among intervention protocols (i.e. duration, follow-up period, and frequency of exercise) may be another factor. The results of this meta-analysis suggest that duration and dosage of exercise are major factors because the participants who received at least six weeks of treatment showed greater improvements than those who only received four weeks of treatment. This is an extremely important consideration for clinicians and future researchers as they design their exercise protocols for females with PFPS because even though the subjects' scores still improved following the shorter intervention periods, greater improvements were displayed in the groups that had longer treatment periods and more treatment sessions. Consideration must also be given to the fact that some participants in the included studies received up to 30 treatment sessions, which may be more visits than typically allowed by most insurance plans. Clinicians need to consider this when applying the results of this review to clinical practice, and prescribe a strong home exercise program based on the design of the included studies in this review combined with adequate patient education, which may allow patients to achieve the desired results despite a limited number of visits.

A potential limitation of this review is the exclusion of non-English language studies. The exclusion of studies that did not have separate data available for males and females is another potential limitation. These studies observed the effects on both genders and did not present data to analyze the differences between genders. These were excluded because they did not address the research question, however, this could have left out potentially useful information and data. One final limitation of this particular study is that along with the relatively small sample sizes of each individual study, this review itself only included five studies, which limited the total number of participants to be included in the aggregate calculations and comparisons. Undoubtedly, had more studies been included the recommendations to be made could have been stronger.

Based on the findings of this systematic review and meta-analysis, the use of a multi-joint protocol can be supported for the reduction of pain in females with PFPS. However, there are still inconsistencies in the findings for improvement in function within this population. Therefore, more research needs to be conducted with larger sample sizes and more consistent exercise dosage, which could provide more definitive findings that would support a stronger recommendation for the use of a multi-joint exercise protocol in improving function in females with PFPS. Future research should continue to focus on gender-specific data and further investigate both short- and long-term outcomes of multi-joint exercise programs for females with PFPS. Increasing the study sample sizes, greater uniformity of duration and dosage of exercise protocols, and standardizing universal outcome measures to assess pain and function could help reduce variability in data reporting in future studies.

CONCLUSIONS

Previously conducted systematic reviews and meta-analyses have concluded that there is not enough strong statistical evidence to support the use of a multi-joint exercise approach compared to a single joint approach when including both male and female participants.[5,12,13] However, this systematic review and meta-analysis found statistically significant outcomes and strong effect sizes in favor of using a multi-joint protocol in comparison to single joint protocol for all areas analyzed, except short-term self-reported function and long-term functional performance, for reducing pain and improving function in females with PFPS.

The included studies were similar in terms of the population measured, which allows these findings to be generalized to many different clinical settings. These findings allow for a strong recommendation to be made for the use of a multi-joint protocol for the reduction of pain in females with PFPS; however, more research needs to be completed for a strong recommendation to be made for the improvement of function in this population.

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